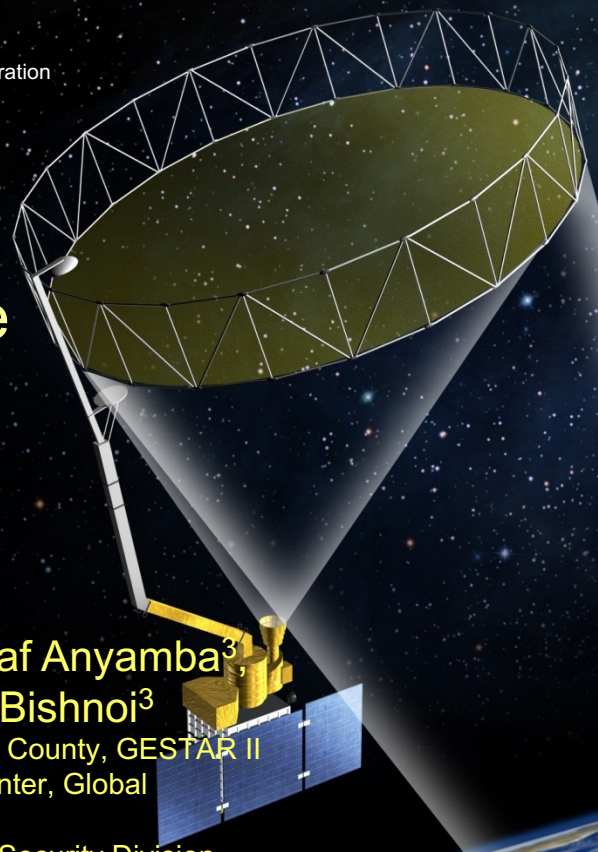
National Aeronautics and Space Administration

Soil Moisture Active Passive Mission

SMAP

Variability in SMAP Soil Moisture Patterns and Vector-Borne Disease Outbreaks: Some Recent Observations



Natalie Thomas[1,2], Assaf Anyamba[3], Heidi Tubbs[3], Bhaskar Bishnoi[3]

[1]University of Maryland Baltimore County, GESTAR II

[2]NASA Goddard Space Flight Center, Global Modeling and Assimilation Office

[3]Geospatial Science and Human Security Division, National Security Sciences Directorate, Oak Ridge National Laboratory

SMAP ST Meeting #17

February 15, 2023

Outline

1. Background
2. Case study: 2020 Sahel Floods
3. 2022 Soil Moisture anomalies and disease outbreaks
4. Global chikungunya outbreaks and associated soil moisture patterns (preliminary)

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Background

- Rainfall, temperature and vegetation index are commonly used in studies of vector-borne diseases (VBDs); soil moisture is less well-studied in this context, even though it is an important determinant of vector habitat suitability – vector populations depend on surface water availability

- Climate extremes are critical to mosquito vector survival, reproduction and development

- VBDs mentioned in this talk:
  - Rift Valley Fever
    - Crossover vector-borne viral disease that commonly affects both domestic animals and humans.
    - Outbreaks of RVF are closely linked to persistent and above normal rainfall. This is due to flooding of ground pools known as dambos that serve as production habitats for mosquito eggs.
  - Chikungunya
    - Viral mosquito-borne disease that can spread rapidly over large geographical areas leading to significant morbidity.
    - The role of soil moisture on chikungunya risks has not been explicitly identified, but evidence indicates that elevated temperatures during drought conditions and temperature induced dehydration have positive effect on Chikungunya vectors

Background

- The objective of this proposal is to enhance risk mapping and forecasting skill of a suite of vector-borne diseases models through the use of soil moisture data from SMAP mission.

- Proposal Tasks
  a) Data processing: disease data, soil moisture and other relevant climate data;
  b) soil moisture anomaly evaluation;
  c) Identification of extreme events by soil moisture anomaly;
  d) Characterizing soil moisture conditions in association with disease outbreaks;
  e) Disease risk model development with SMAP data.

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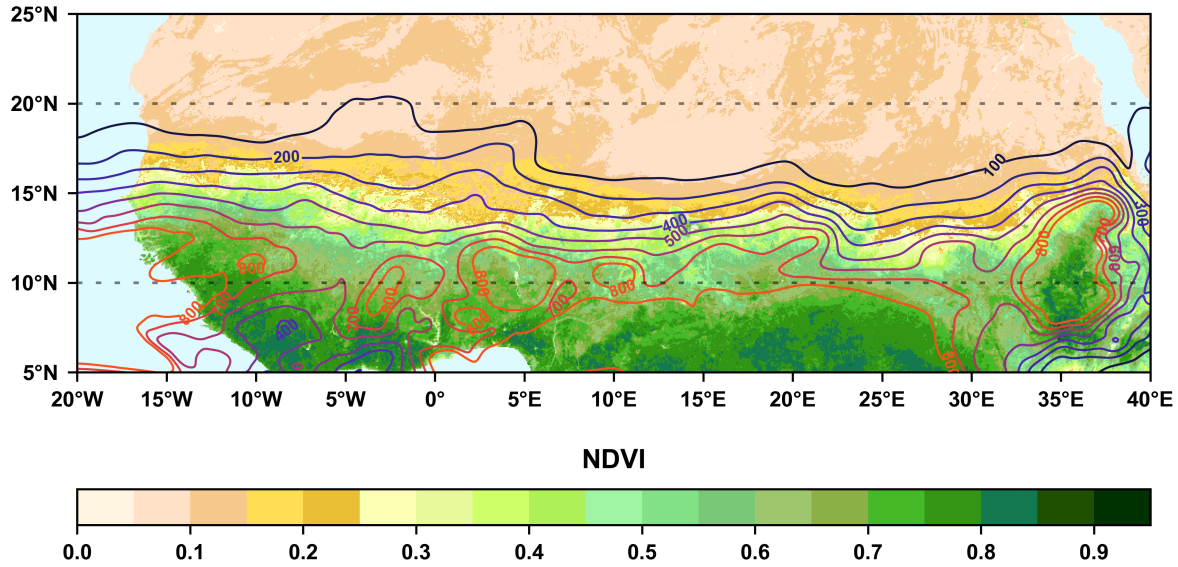
2020 Sahel Floods – Historical Context

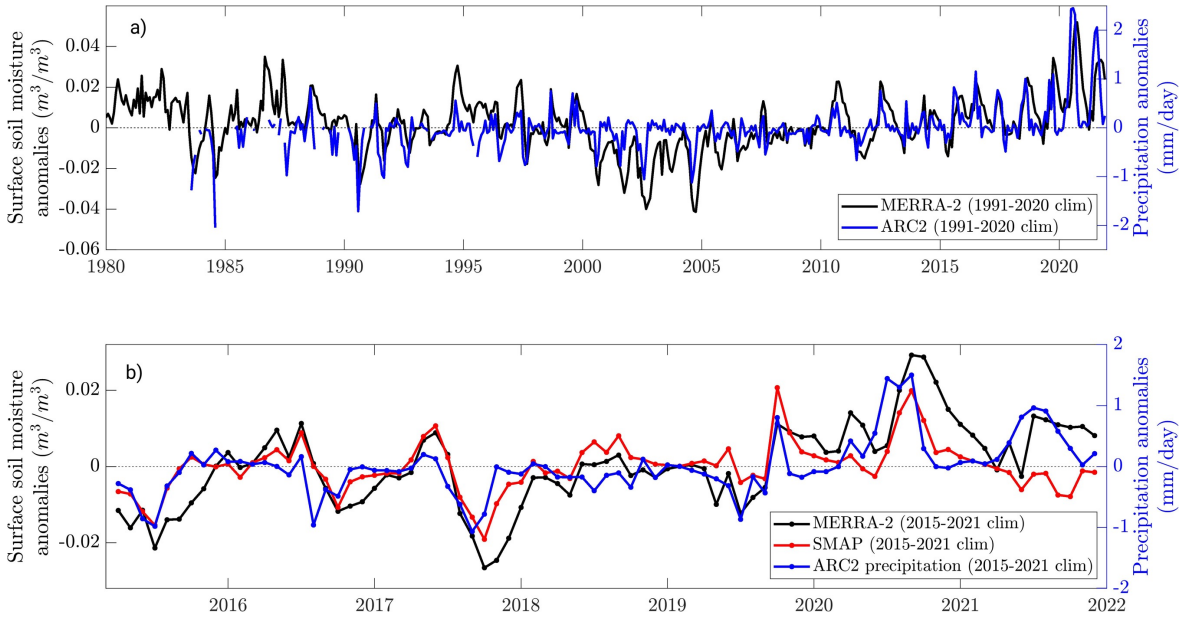


- The African Sahel is an ecologically and climatically sensitive region, and thus is a valuable test case for examination of climate extremes

- Extreme rainfall combined with urbanization and land-cover change has caused flooding events to become more destructive in the Sahel

2020 Sahel Floods – Historical Context

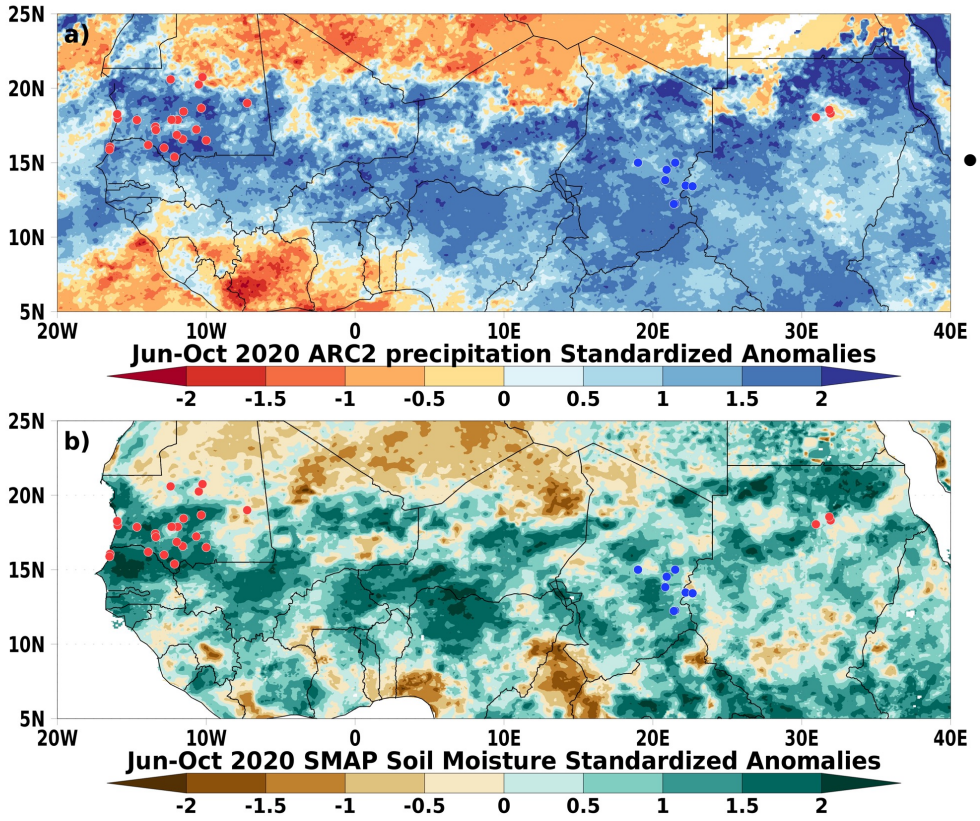
- Summer of 2020: prolonged and extreme rainfall throughout the Sahel
- Most extreme anomalies in record, as seen by:
  - SMAP L4 V6 surface soil moisture
  - MERRA-2 surface soil moisture
  - ARC2 precipitation



Rank	1980-2021		2015-2021		
	MERRA-2 surface soil moisture	ARC2 precipitation	MERRA-2 surface soil moisture	ARC2 precipitation	SMAP soil moisture
1	2020	2020	2020	2020	2020
2	2021	2021	2021	2021	2018
3	1986	2019	2018	2019	2019
4	1994	2018	2016	2018	2016
5	2018	2016	2019	2016	2021

Rank of positive anomalies in seasonal (June-October) precipitation and soil moisture averaged over the Sahel for 1980-2021 and 2015-2021.

2020 Sahel Floods – Anomalies and Outbreaks

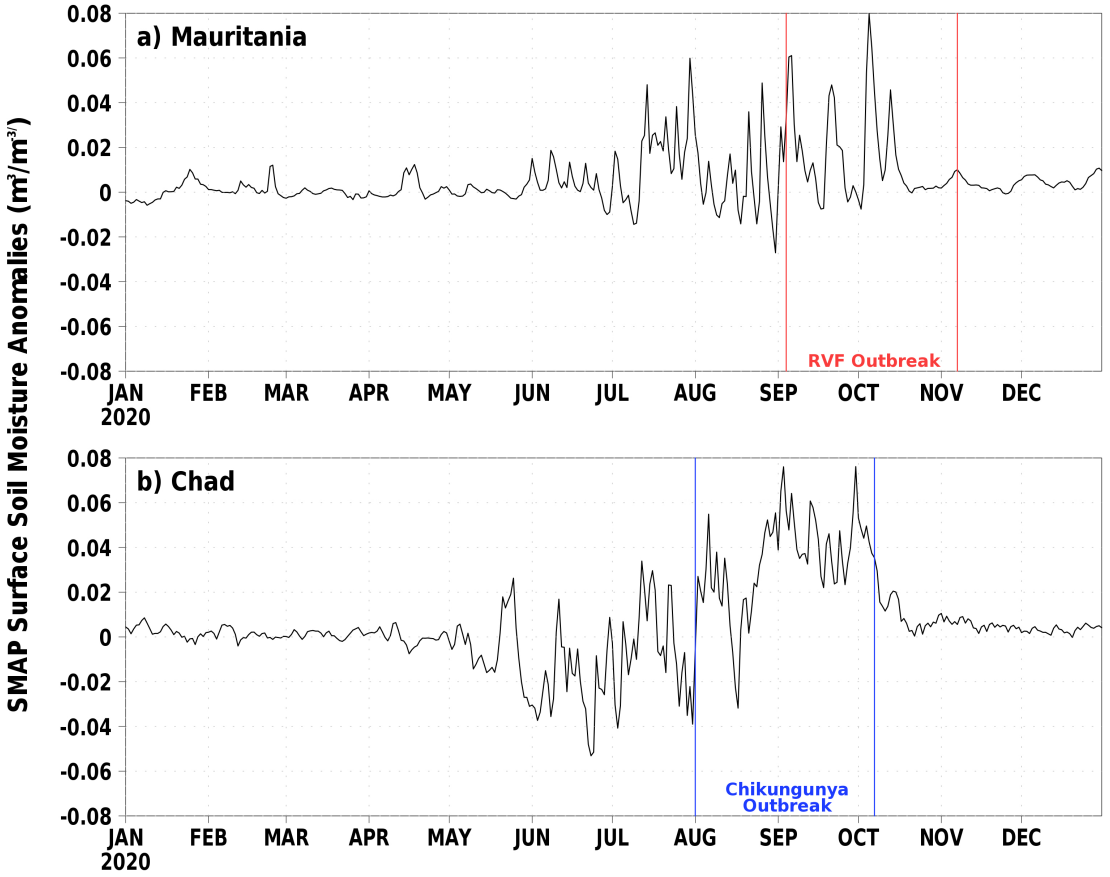


Red dots: Rift Valley Fever outbreaks
Blue dots: Chikungunya outbreaks

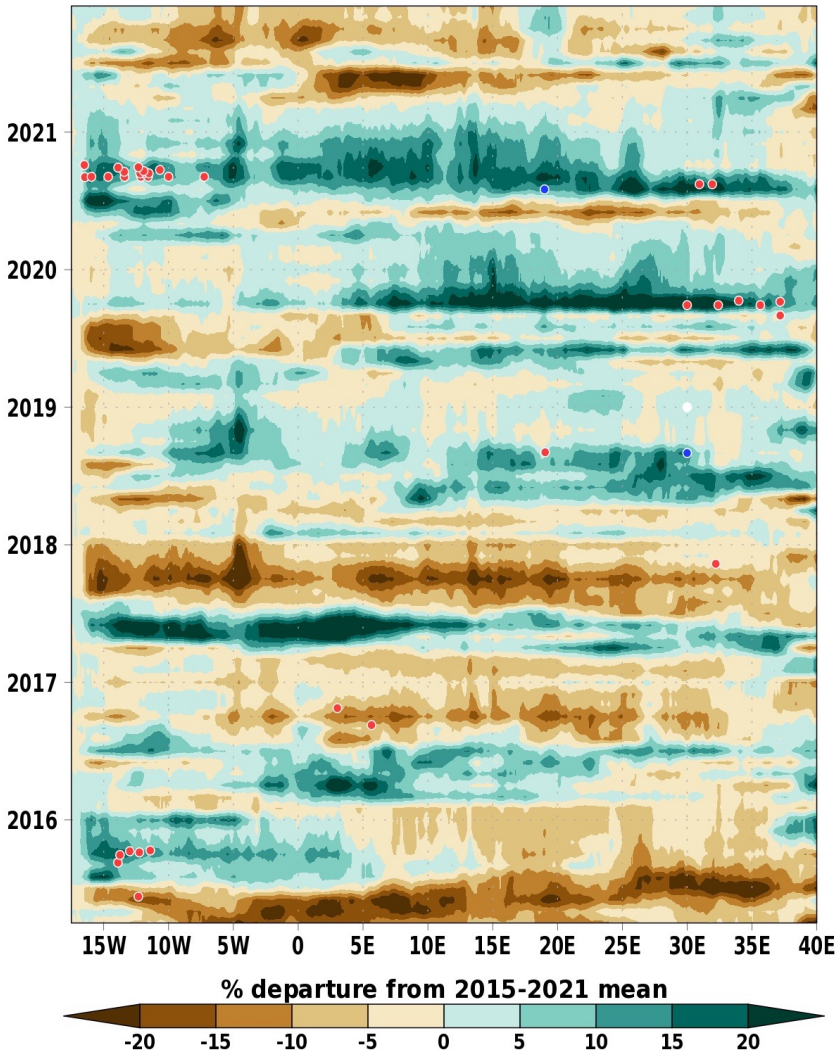
- JJASO soil moisture and precipitation anomalies both show above-normal values throughout the Sahel
- Concurrent VBD outbreaks:
  - RVF in southern Mauritania: very anomalously positive surface soil moisture and seasonal precipitation. soil moisture anomalies may be a better indicator of the risk of a precipitation alone?
  - RVF in Sudan: seasonally averaged anomalies in both precipitation and soil moisture were weakly positive
  - Chikungunya in Chad: relatively large positive anomalies in both precipitation and surface soil moisture in the seasonal average.

2020 Sahel Floods – Daily SMAP anomalies

- Mauritania: RVF outbreak began in early September, approximately 2 months after the start of the strongest soil moisture anomalies.
- Chad: Chikungunya outbreak began in early August, about two months following the start of negative soil moisture anomalies. The surface soil moisture anomalies were strongly positive around the same time as the start of the outbreak in early August



Sahel Floods and Outbreaks: beyond 2020



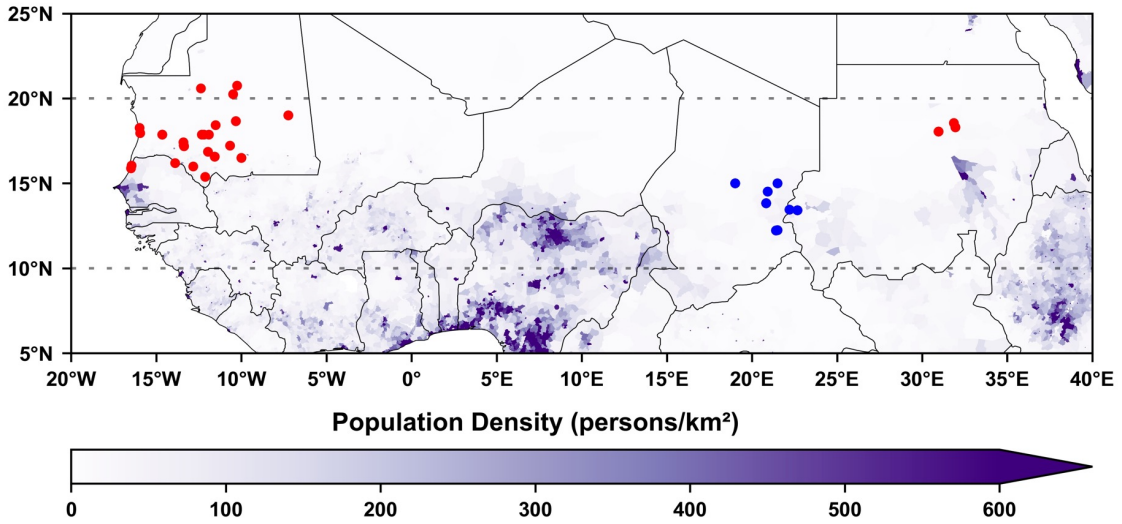
Red dots: Rift Valley Fever outbreaks
Blue dots: Chikungunya outbreaks

- Monthly soil moisture anomalies over the entire SMAP record, averaged over 10-20N at all Sahel longitudes.
- Previous positive soil moisture events in 2015, 2018, and 2019 were also coincident with reported outbreaks of RVF in different locations across the Sahel
- Reported outbreaks of Chikungunya in the Sahel have been much rarer, and thus broad patterns are not as obvious.

2020 Sahel Floods – other factors affecting outbreaks

Many other factors beyond climate conditions that can affect outbreaks of diseases

1. Population density
   - Source areas of 2020 Sahel outbreaks were relatively low-density population areas
2. Levels of immunity in the population
   - Before 2020 no previous records of Chikungunya in Chad
3. Changes in land cover
   - Can affect suitability for vector habitats, such that even if there is an extreme climate anomaly, it may not lead to an outbreak.
4. Limitations and reporting biases of disease surveillance systems can hinder the ability to detect all outbreaks.



2020 Sahel Floods - Conclusions

- Multiple data products, including SMAP L4 surface soil moisture, revealed the 2020 growing season floods in the African Sahel to be extreme with respect to recent decades.
- Flooding such as this can have many societal consequences, among them the outbreak of vector borne diseases.
- Precipitation, temperature and NDVI are the climate variables typically used in studies of VBD outbreaks. This study represents a first step in employing satellite-based soil moisture data to examine the relationship between hydrometeorological extremes and VBD outbreaks.
- During 2020, Mauritania and Sudan saw outbreaks of RVF, which has previously been linked with persistent above-normal rainfall. Seasonally averaged soil moisture during June-October 2020 showed strong correspondence with the RVF outbreak in Mauritania, suggesting this may be a better indicator of risk than precipitation alone.
- Relationships between Chikungunya and soil moisture need to be explored further

Thomas, N. P., A. Anyamba, H. Tubbs, and B. Bishnoi. 2022. "Evaluation of Extreme Soil Moisture Conditions During the 2020 Sahel Floods and Implications for Disease Outbreaks." *Geophysical Research Letters*, 49 (19): [10.1029/2022gl099872]

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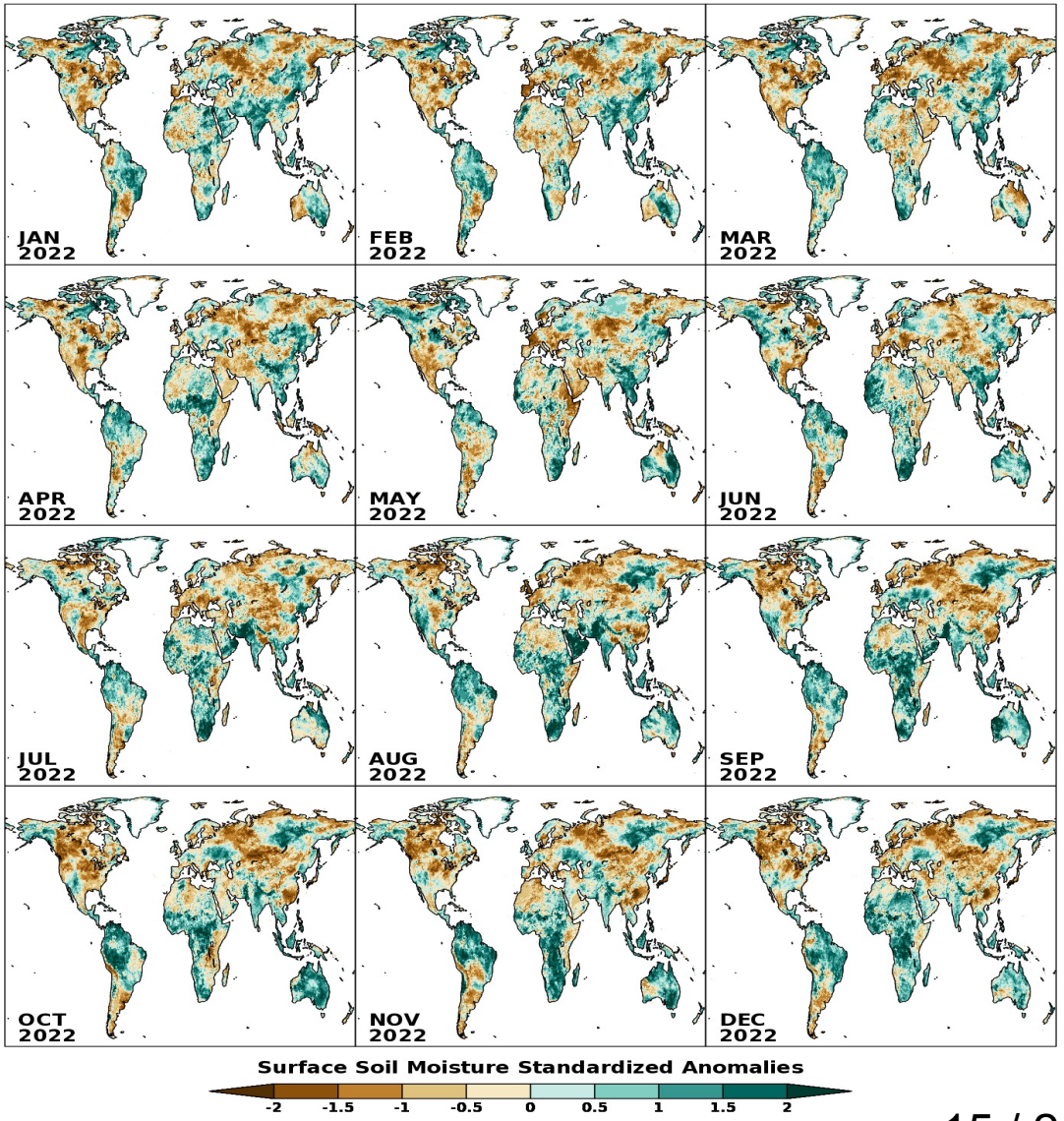
2022 SMAP Anomalies and Disease Outbreaks

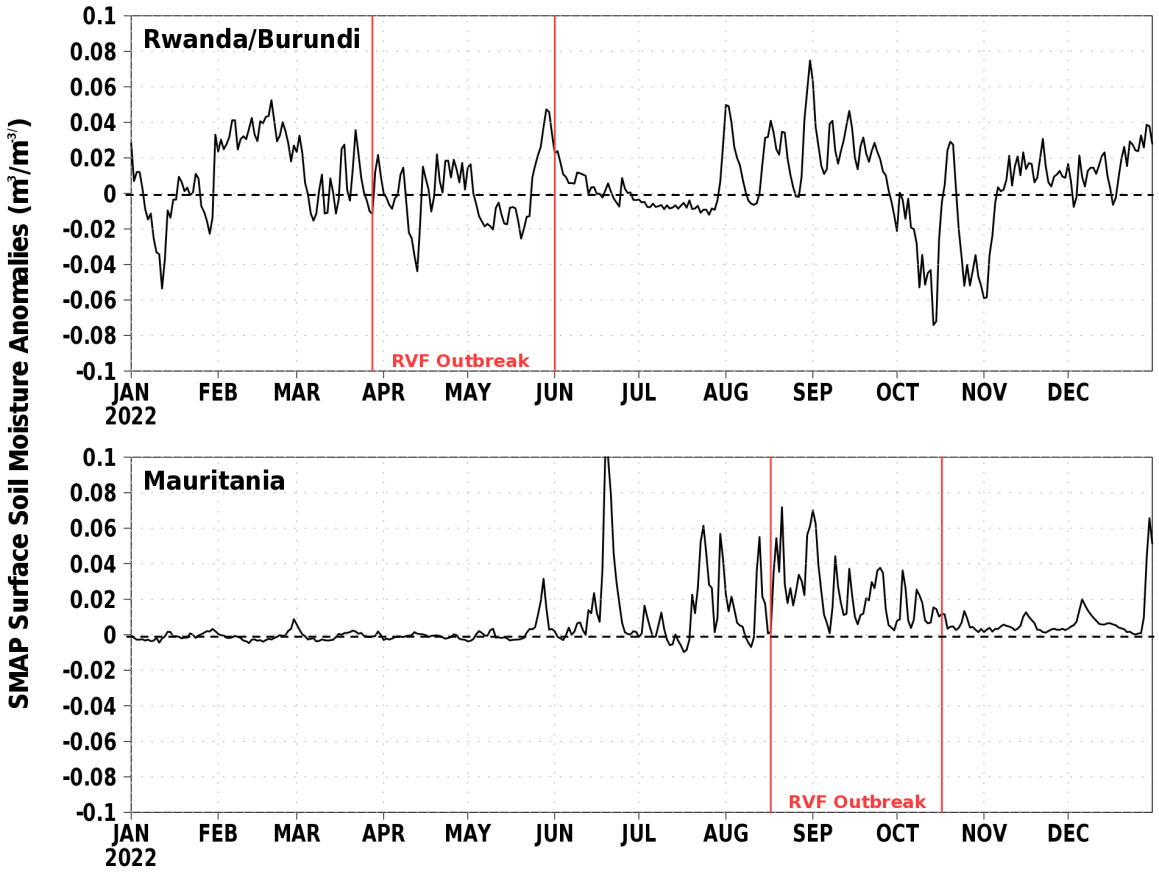
- SMAP L4 V7 monthly surface soil moisture standardized anomalies
- 2022 Rift Valley Fever outbreaks in the Sahel and central Africa
- 2022 Chikungunya outbreaks in Brazil and India



2022 SMAP Anomalies and Disease Outbreaks

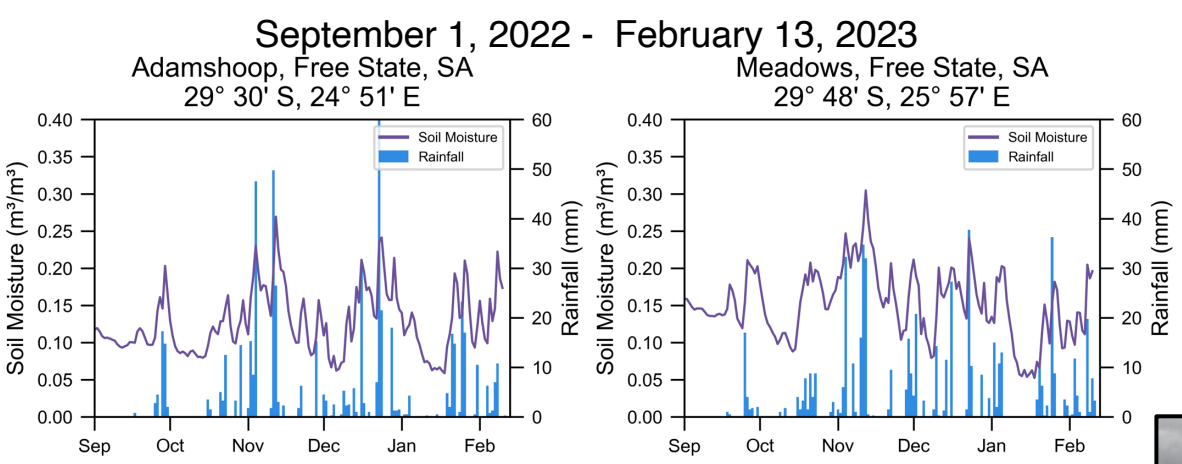
Outbreaks in Rwanda/Burundi began in late March – about 2 months following positive soil moisture anomalies in February

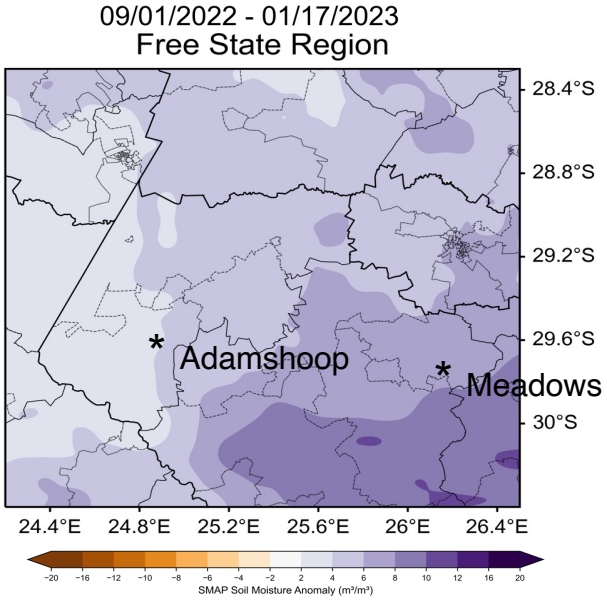
Outbreaks in Mauritania began in mid-August – positive soil moisture anomalies began in late May. Continued RVF outbreaks in Mauritania follow La Niña, and above normal rainfall and soil moisture creates appropriate habitats for RVF mosquito vectors



2023 Field Work

- After 3 years of Covid – resumed RVF field work in South Africa
- Big changes at vector habitat sites, Adamshoop *dambo* is now populated with dense mat of grass
- On going rainfall and + soil moisture anomalies associated with La Nina





February 2, 2023

January 31, 2023

Water boundary in 2019

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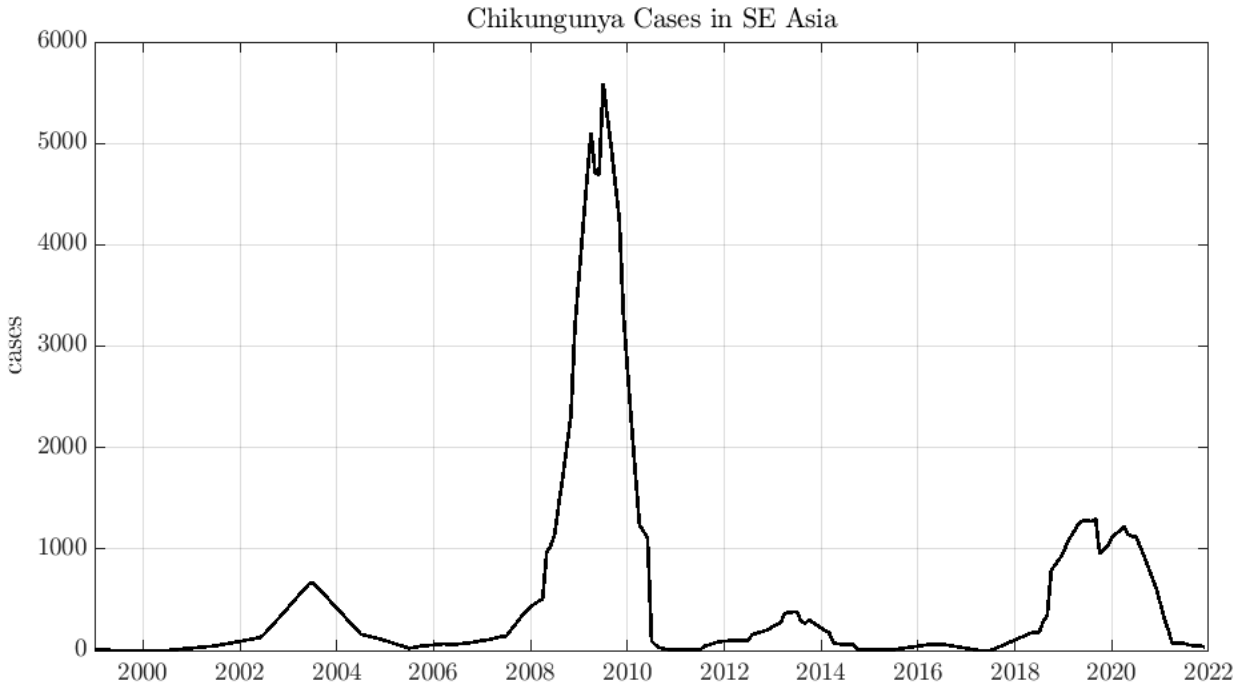
4. **Global chikungunya outbreaks and associated soil moisture patterns (preliminary)**

Chikungunya and SMAP

- Southeast Asia
  - Since 1999, cases recorded in Malaysia, Indonesia, Singapore, Thailand, Cambodia, Myanmar, Philippines



12-month running mean of cases aggregated in the region

Chikungunya and SMAP

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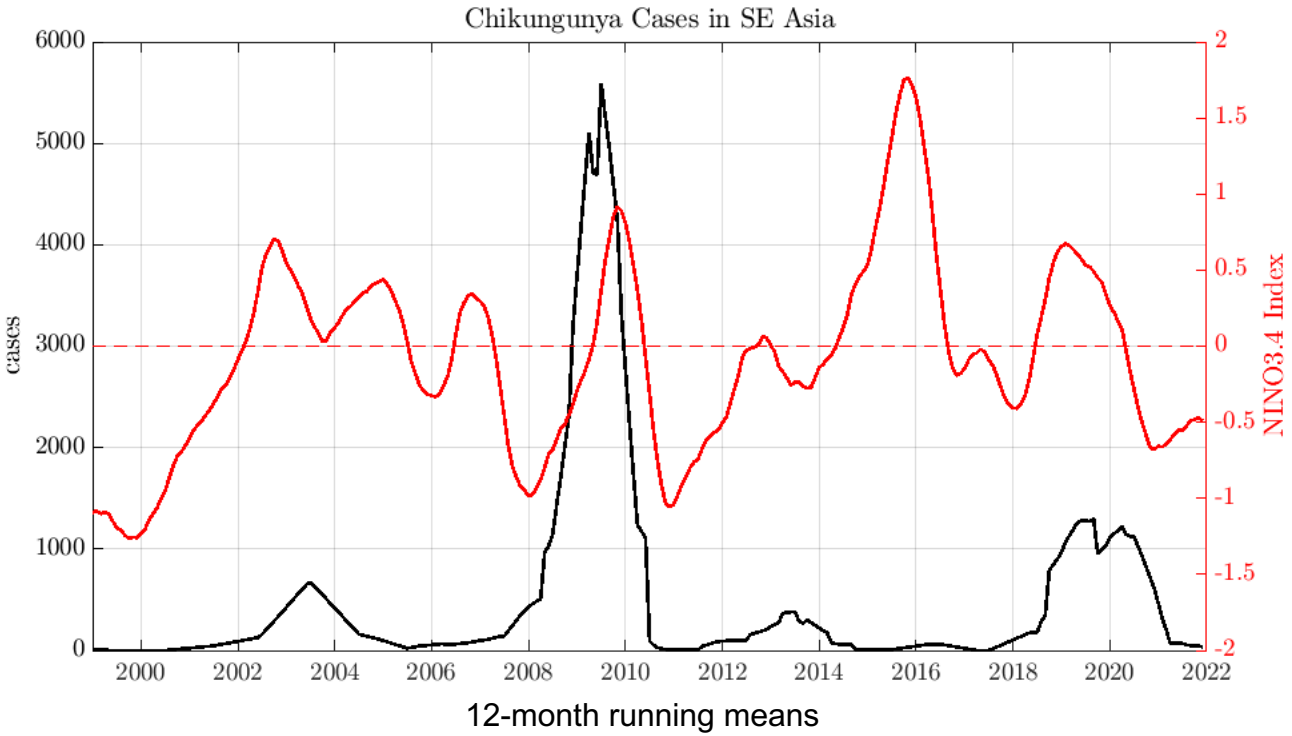
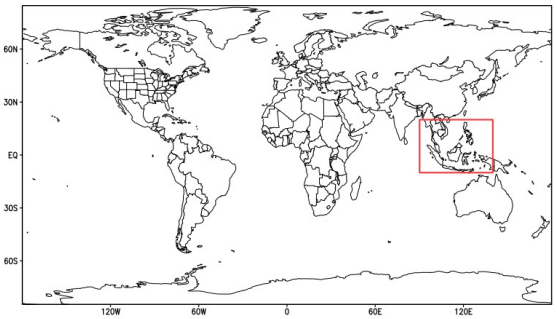
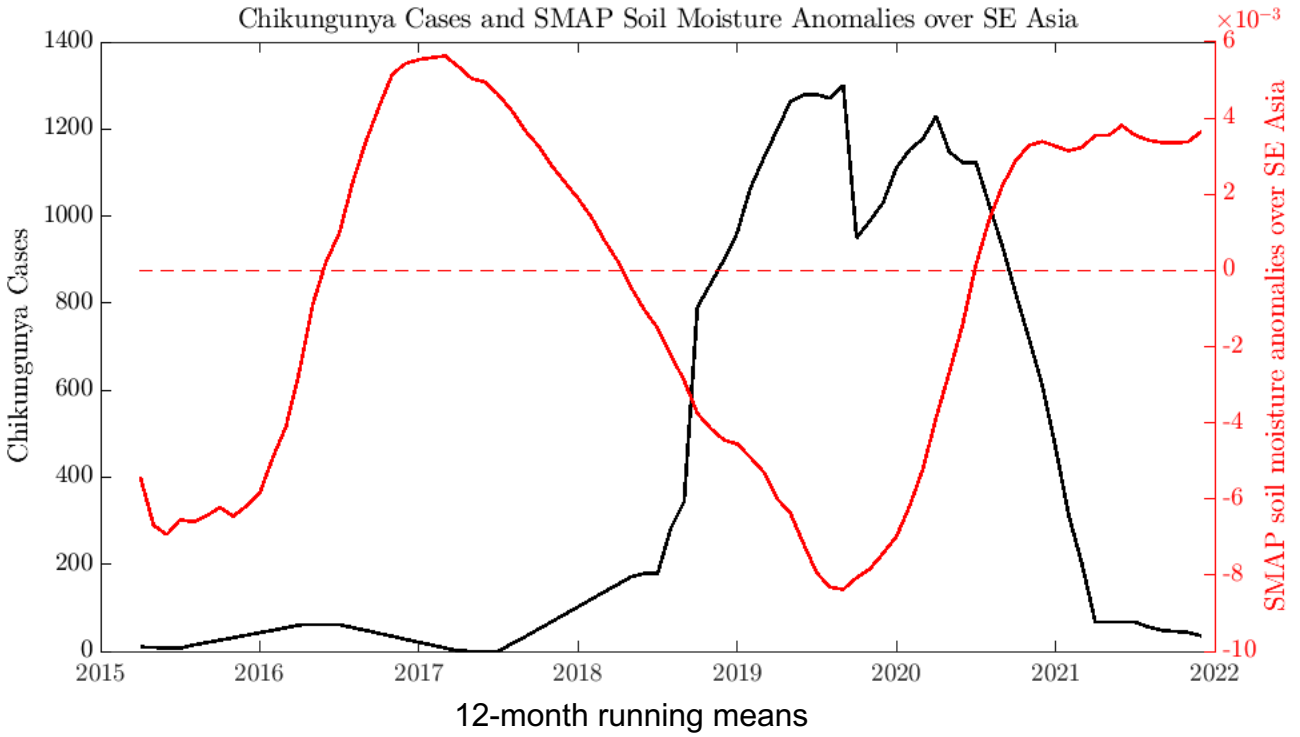


  - Possible relationship between Chikungunya cases and El Nino events over SE Asia (2003, 2009, 2018) – but not always (i.e, 2015 event), consistent with Anyamba et al. (2019)

Chikungunya and SMAP





- Possible evidence for inverse relationship between soil moisture and chikungunya outbreaks in SE Asia
- More work needed

Conclusions

- Case study of 2020 floods in the Sahel revealed connections between extreme SMAP soil moisture anomalies and outbreaks of VBDs
  - RVF outbreaks in Mauritania and Sudan began ~2 months after start of positive soil moisture anomalies
  - Chikungunya outbreak in Chad began ~2 months after start of negative soil moisture anomalies but concurrent with positive soil moisture anomalies

- The RVF – soil moisture relationship corroborated by the outbreaks in Rwanda/Burundi and Mauritania in 2022

- Ongoing work is focused on further exploring the relationships between soil moisture anomalies and outbreaks of Chikungunya. Preliminary results suggest inverse relationship over Southeast Asia - we'll be exploring other regions/diseases including Dengue, Hantavirus and Plague

- RVF shows most promising results - RVF model will be implemented to include SMAP Soil Moisture

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